学校编码：10384

学号：23120101152939

厦门大学

硕 士 学 位 论 文

基于圆环结构的新型光纤光栅器件及传感器的设计与研究

Design and Research of the Novel Fiber Bragg Grating Devices and Sensors Based on the Circular Ring

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答辩日期：2013年6月

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摘 要

经过四十多年的发展，光纤光栅已成为了光通信和光纤传感领域不可或缺的重要角色，也成为了科研工作者和科技型公司争相研究的新宠。现代信息社会对信息传输的高速率要求和工程应用对高性能传感器的需求是促进光纤光栅器件及传感器快速发展的最大助力。因此，研究新的光纤光栅技术具有非常重要的意义。

本文以在机械和力学领域被广泛应用的圆环结构为核心元件，讨论了不同参数的光栅及安装方式所得到的不同结果，研究内容主要体现在以下三个方面：

一、 利用薄壁圆环在受一对集中力压缩/拉伸时内外表面产生的规律分布的正负应变场，提出了一种新的可调谐啁啾Bragg光栅(TCFBG) 实现方法。该方法的色散调谐灵敏度高，结构紧凑，可靠性高，且易于实现，为光通信系统中光信号长距离传输产生的色散提供了一种有效的补偿方案。

二、 提出了基于薄壁圆环的光纤Bragg光栅传感器在力传感领域的应用方案，借鉴电阻应变片的测力环结构设计了一款高分辨率的测力传感器，利用啁啾光栅的传感特性制成了一种用一根光栅同时测量压力/拉力和温度的传感结构，并从理论和仿真结果上分析了啁啾光栅3dB带宽线性展宽过程中光栅反射功率非线性增加的原因。最后从实验上验证了利用薄壁圆环制作的微位移传感器的传感特性，其表现出了良好的灵敏度和线性度。

三、 在加速度传感器力学模型的基础上，借鉴前人的科研成果，分析了圆环的动态特性，探讨了圆环结构尺寸、光栅粘贴方式及重物、底座固定方式对系统谐振频率的影响，并提出了一种新的光纤Bragg光栅加速度传感器的设计理念，并在这一理念下提出了等强度悬臂梁和薄壁圆环并联式的传感结构，在相同的谐振频率下获得了六十倍于等强度梁原有灵敏度的提升量。通过有限元分析软件ANSYS对所优化的结构进行了力学特性的分析。

关键词：光纤光栅；光纤传感器；薄壁圆环

Abstract

After forty years of development, the Fiber Grating has been an indispensable role in the field of optical communication and optical fiber sensing, and has also become the new hot spot in which a large amount of researchers and high technology companies compete to research. The requirement of high rate in information transmission and demand of high-performance sensors by engineering applications promote heavily to the rapid development of fiber grating devices and sensors. Therefore, the study of new fiber grating technology has a very important significance.

The circular ring which is widely used in the field of machinery and mechanical was discussed as the core structure in this thesis, with the different parameters of the grating and install patterns the different results were obtained. The researchs were mainly reflected in the following three aspects:

First, by use of the strain curve of the inner and outer surface of the thin-walled circular ring which been compressed or stretched, a new tunable chirped fiber Bragg grating (TCFBG) fabricate method was realized. The convenient dispersion tuning function provided an effective method to compensate the dispersion which is generated by light signal under a long-distance transmission in optical communication system.

Second, an application scheme of the new fiber grating sensor which based on a thin-walled ring was proposed. By learning from the principle of a proving ring with the resistance strain gauge installed one designed a high-resolution load cell. By use of the sensing properties of chirped gratings one made a sensing structure which can simultaneously measure external force and temperature. Then analyzed the reasons in theory and simulation about nonlinear increase of the reflection power of the CFBG while its 3dB bandwidth has a linear broadening. Then experimentally validated a good sensitivity and linearity of a micro-

displacement sensor which use the thin-walled ring.

Third, on the basis of the mechanical model of the acceleration sensor and drew lessons from previous research results, one analyzed the dynamic characteristics of the circular ring with different ring structure sizes, grating paste patterns, heavy and base-block fixed modes. Then a new fiber Bragg grating acceleration sensor design concept was proposed. And under this concept a parallel sensing structure consisted of a cantilever beam of constant strength and a thin-walled ring is realized, which obtained a sixtyfold promotion on sensitivity against the original in the same resonance frequency. By use of the FEA software ANSYS, the mechanical properties of the optimized structure is analyzed.

Keywords: Fiber Bragg Grating; Fiber Sensors;Thin-walled Circular Ring

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